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June, 1938

THE JAPANESE BEETLE IN CONNECTICUT

W. E. Britton and J. P. Johnson

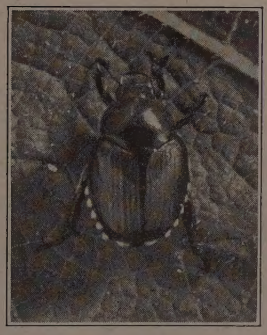

Figure 69. Japanese beetle.
Twice enlarged.

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FIGURE 70. Japanese beetles feeding on hollyhock. Natural size.

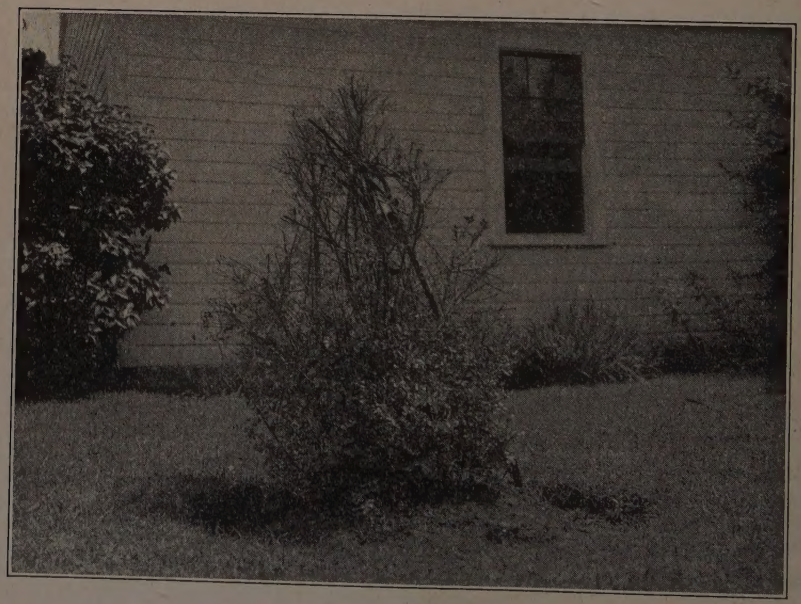

FIGURE 71. Rose bush nearly stripped by Japanese beetles, Bridgeport.

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The Japanese Beetle in Connecticut

W. E. Britton and J. P. Johnson

THE Japanese beetle, *Popillia japonica* Newman, was first discovered in Connecticut at Stamford, September 1, 1926. Since that time this insect has become widely distributed throughout Connecticut and at present all cities and nearly all of the larger villages are infested. Already it has been responsible for considerable local damage that has been observed and recorded. However, it has not yet become a pest in the open country, but in a few years will probably cause widespread damage to lawns, gardens, ornamental and native shrubs, and fruit, shade and woodland trees. The purpose of this bulletin is to bring together in one publication certain pertinent facts regarding the Japanese beetle so that property owners may obtain information about it and employ the best methods of protection.

The Beetle in its Native Land

This beetle is indigenous to the principal islands of Japan but it has not been found on the mainland of Asia. According to Smith and Hadley (15), it is common but not abundant on the islands of Kyushu and Shikoku, and is usually more numerous in Honshu from Yokohama northward. The soybean is one of the important crops in Saitama, Tochigi and Fukushima, and in these sections the beetles at times are sufficiently numerous to cause some damage. Farther north on the island of Honshu heavy infestation often occurs, but the beetles feed chiefly on a species of smartweed, *Polygonum reynoutria*, that grows abundantly along the roadsides. The beetles also occur throughout the island of Hokkaido, where they sometimes damage crops. However, the insect is not regarded as a serious pest in Japan, probably because of the absence of extensive breeding areas. Although there are often large areas of preferred food plants, breeding is difficult under the Japanese system of intense cultivation. Native parasites also undoubtedly help to hold this beetle in check.

Discovery and Spread in the United States

The first evidence of the occurrence of this insect in the United States was obtained in the summer of 1916 by E. L. Dickerson and H. B. Weiss of the New Jersey State Department of Agriculture, who collected a few beetles unfamiliar to them in a nursery near Riverton, N. J. Later these beetles were identified by Mr. E. A. Schwarz of the Bureau of Entomology as *Popillia japonica* Newman, a species common in Japan. Thus it was called the Japanese beetle. Prior to 1912 many plants with balls of soil about their roots were imported from Japan, and some shipments had been received in the locality where these beetles were collected. It is very probable that grubs or larvae were present in the soil of some of this nursery stock and started the infestation.

In 1917, scouting showed that the infestation covered about 2.7 square miles, of which half a square mile was heavily infested. By 1920 this insect had spread over 92 square miles in New Jersey, and 11 in Pennsylvania, or a total of 103 square miles. By the end of 1923, 2,422 square miles were infested, 1,744 in New Jersey and 698 in Pennsylvania.

Thus the Japanese beetle continued to spread rapidly until 1937, when the Federal Quarantine covered the states of New Jersey, Delaware, and the District of Columbia, all of Pennsylvania except six counties in the northwestern corner of the state, all of Connecticut, Rhode Island, Massachusetts, a small area in the southwestern portion of Maine, the southern half of New Hampshire and Vermont, the southeastern portion (nearly half) of New York and small portions of Ohio, Maryland, Virginia and West Virginia. In addition to the quarantined areas, many isolated or scattered infestations have been discovered in Georgia, Illinois, Indiana, Kentucky, Maine, Maryland, Michigan, Missouri, North Carolina, Ohio, South Carolina, Tennessee, Virginia and West Virginia. Altogether these quarantined areas cover more than 100,000 square miles.

Discovery and Spread in Connecticut

On September 1, 1926, federal scouts found a few Japanese beetles in Stamford and this was the first evidence that the pest was present in Connecticut. The beetles were in three yards on the south side of Broad Street, between Summer and Winthrop Streets, and nearly opposite the south end of Franklin Street. One beetle was found north of Broad Street. Altogether 18 beetles were taken in Stamford that season.

The following summer, 211 beetles were found in Bridgeport and one each in Darien and New Canaan, or 213 altogether. In 1928 infestations were found in Hartford, 12 beetles; New Haven, 19 beetles; and New London, 27 beetles. About 48 towns and cities were scouted. In 1929, 863 beetles were caught in Hartford and 168 in New London. In Hartford eight men working six days treated 107,200 square feet of lawn with 40,200 gallons of diluted carbon disulfide emulsion. In New London, seven men in two days treated 27,200 square feet of lawn with 10,200 gallons of diluted emulsion. In scouting 67 cities, towns and villages in that season, the only new infestations discovered were in East Haven, West Hartford and in Willimantic where 12 beetles were taken.

In 1930 beetles were collected as follows: Hartford, 3,095; New London, 220; Willimantic 17—making a total of 3,332. No attempt was made to collect beetles in the Stamford-Bridgeport-New Haven area, which had then been placed under quarantine. Scouting was carried on in 97 cities, towns and villages, six of which were found infested for the first time as follows: Branford, 118 beetles; Danbury, 31; Enfield, 3; Groton, 1; Meriden, 2, and Terryville, 1.

The first lawn treatments with lead arsenate were applied in Hartford, New London and Willimantic. The poison mixture contained: Lead arsenate 1 part, tankage 2 parts, and sand 4 parts. It was applied at the rate of 1,500 pounds per acre, one-third the amount required, and equal amounts were to be applied in two later treatments. Altogether, 87 tons of this mixture were used. In Hartford about 65 tons were used in several

areas totaling about 85.5 acres. In New London, about 15 tons were applied to about 19.5 acres, and in Willimantic approximately 9.2 acres were treated with nearly seven tons. Altogether the Hartford, New London and Willimantic applications covered 114.2 acres and cost approximately $7,927.02, or an average of $61.53 per acre. Some complaints were received because cats and dogs ate some of the tankage and were made sick by the lead arsenate. Tankage has not since been used in Connecticut as a carrier in the application of lead arsenate.

In the same year, 1930, Federal Quarantine No. 48 was revised to include the entire State of Connecticut, designating the former regulated area in the southern portions of Fairfield and New Haven counties as the generally infested area and the remainder of the State as the lightly infested area.

In 1931 the number of beetles collected around the old infestations, outside the former regulated area, was as follows:

Danbury	67	Meriden	32
Enfield	1	New London	385
Groton	4	Willimantic	15
Hartford	3,295		
		Total	3,799

Scouting operations were carried on in 55 cities and towns and the following new infestations found: Norwich, 1 beetle; Old Saybrook, 1; Ridgefield, 771; and Torrington, 1. The greater portion of the areas in Hartford, New London and Willimantic treated in 1930 with dry lead arsenate, tankage and sand, were further treated with lead arsenate and water, applied as a spray by means of truck power sprayers with 600-gallon tanks, owned by the Bureau of Entomology. Statistics of this treatment are as follows:

	Acres	Pounds lead arsenate
Hartford	51.75	22,250
New London	17.51	7,500
Willimantic	12.36	6,050
Total	81.62	35,800 = 17.9 tons

Changes were made in the State Quarantine by adding Branford to the generally infested area and including the remainder of the State in the lightly infested zone in compliance with Federal Quarantine No. 48, as revised in 1930.

In 1932, 46 cities and villages were scouted and new infestations found in Bristol, East Hartford, Hamden, Milford, Mystic, New Britain, Norwalk, Shelton, Waterbury and West Haven. No soil treatment was attempted. Federal Quarantine No. 48 was revised to include Rhode Island and portions of Massachusetts and New York, and the two-zone system was abolished. As this quarantine not only included the whole of Connecticut but also extended the regulations over territory far beyond the borders of the State, there seemed to be no further need for the State Quarantine and it was revoked February 10, 1932.

In 1933 by means of traps, beetles were found for the first time in Manchester, Middletown and Putnam. The infestation in Bridgeport had in-

creased to such an extent that adult feeding damage was evident on grapevines, shrubs and flowering plants in many localities, and complaints by telephone and mail were numerous.

In 1934 Japanese beetles were taken for the first time in Ansonia, Naugatuck and Wallingford. They were more numerous than ever before in the older centers of infestation—Bridgeport, Hartford, New Haven and Stamford.

In 1935 beetles were found for the first time in North Haven, Stratford, Waterford, Windsor and Windsor Locks. Around the old infestations they continued to increase in numbers.

A year later beetles were found for the first time in Canaan, Fairfield, Ledyard, Litchfield, New Milford, Newtown, Southbury, Westport, Wethersfield and Winsted. Apparently there was no marked increase in the number of beetles in the old infestations except in Bridgeport, Hartford and Ridgefield. General feeding and damage occurred only where beetles were abundant. In Bridgeport, general feeding was observed on grapevines, roses, hollyhocks, horsechestnut and sassafras. In Riverside Park, Hartford, the beetles were feeding generally on elm and willow trees, Japanese barberry hedge and flower garden plants. The Hartford Park Department applied 30 or more tons of lead arsenate in treating the turf

FIGURE 72. Eggs. Twice enlarged.

in Riverside Park, Bushnell Park, and that portion of Elizabeth Park in and surrounding the rose gardens. In Ridgefield, on two estates, the beetles fed upon white birch, maple and linden trees, and damaged low-growing plants. In Branford a small amount of feeding was noted on a Japanese red pine and the beetles fed generally on flower garden plants.

In 1937, by means of traps, beetles were found for the first time in Bloomfield, Clinton, Durham, Glastonbury, Guilford, Lakeville, Madison, Norfolk, Southington, Stafford Springs and Thompsonville. Infestations had increased in Branford, Bridgeport, East Hartford, Greenwich, Hartford, New Canaan, New Haven and Ridgefield. In Riverside Park, Hartford, where the turf was treated in the fall of 1936, there was no feeding on elms in the park, but beetles were plentiful on evening primrose in adjacent fields where the hay and weeds purposely had not been cut. In Bridgeport heavy feeding was observed on grapevines, native evening primrose and, in localized areas, on linden, Schwedler maple, sweet cherry and plum. Light feeding was noticed on white birch, elm, weeping willow, sycamore, mountain ash and blackberry. It may be said that general feeding occurred in localized areas in Branford, Danbury, Greenwich, Hartford, New Haven, New London, Ridgefield and Stamford.

Damage to lawns by the grubs of this insect was observed in Branford, Bridgeport, Greenwich, Hartford, New Haven, Ridgefield and Stamford, and small turf areas in Danbury, New London and Putnam were infested to such a degree that damage would have been evident had not the growth of grass been stimulated by the unusually heavy rainfall.

DESCRIPTION

Egg. The eggs are somewhat elliptical and about one-sixteenth of an inch in greatest diameter, when first laid. After remaining in the ground for a week or more they increase to nearly twice their former size and become almost spherical. In color they are translucently white or cream, and they appear finely punctate when highly magnified. The egg is shown in Figure 72.

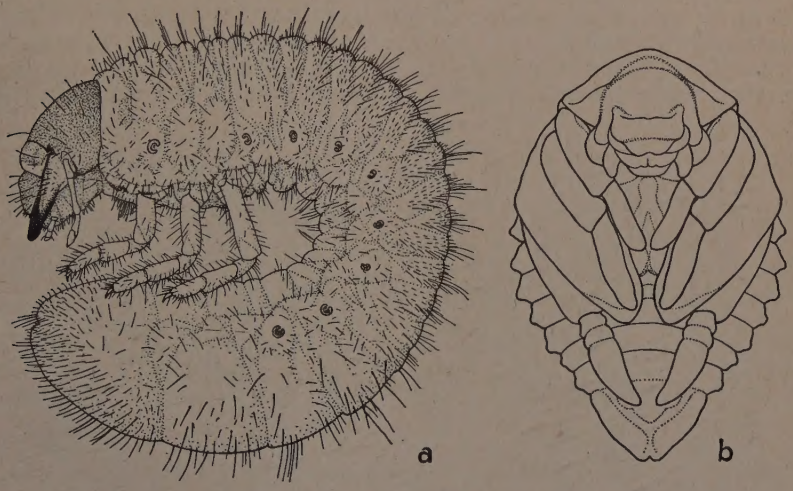

FIGURE 73. a. Grub or larva, lateral aspect. b. Pupa, ventral aspect. Each about five times enlarged.

Larva. When first hatched the larva or grub is about one-sixteenth of an inch in length. It has three pairs of legs and is whitish in color. When mature it is about an inch long, usually is curled up in the soil, and in general resembles other white grubs of which there are many species. The head is light brown and the body white with a bluish tint, much darker at the anal end because of the soil and food waste in the digestive tract. The body also has many transverse folds and bears short bristles. The fully grown larva is shown in Figure 73. For certain identification it is necessary to examine the ventral surface of the anal segment. In the Japanese beetle the last rows of spines occur in a V-shaped arrangement as shown in Figure 74 a. Characteristic structures also occur on the epipharynx, as shown in Figure 74 b, and on mandibles and maxillae as shown in Figure 75. The tarsal claws are approximately of the same size, as shown in Figure 76. When the larva reaches maturity, the accumulated excrement is evacuated from the alimentary canal and the insect becomes pale,

shrunken and inactive. This is called the prepupal stage during which certain changes occur before the grub transforms to the true pupa.

Pupa. The pupa, which occurs in a cell in the soil, is about half an inch in length, light yellow in color at first, later changing to tan. On the dorsal surface heavy transverse ridges indicate the body segments. These ridges also show on the ventral surface, but are partially covered by the closely folded legs and wings. A distinct notch at the apex shows both dorsally and ventrally. At the close of the pupal stage the skin splits along the back and the adult emerges. The appearance of the pupa is shown in Figure 73 b.

Adult. The adult Japanese beetle is slightly less than half an inch in length and about one-fourth of an inch in breadth. Head, thorax, abdomen and legs are bright, shining green, and the wing-covers are copper brown. The wing-covers do not entirely conceal the abdomen which exhibits dorsally, at its apex, two patches of white hairs, and laterally, five additional patches along either side, all of which show plainly when viewed from above. The sexes are similar in color and markings but the males are generally smaller than the females. In case of doubt, the first pair of legs

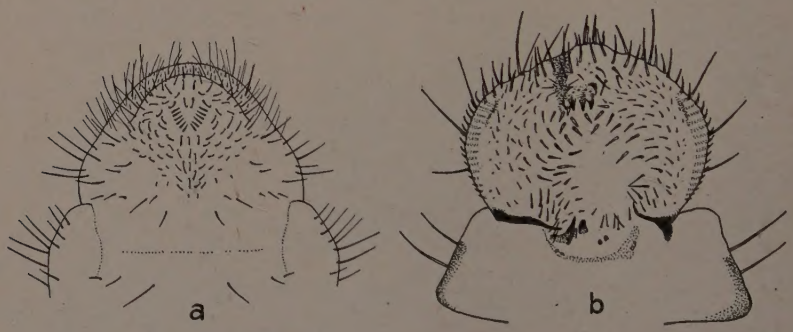

FIGURE 74. a. Ventral aspect of the anal segment of the larva, showing crescent-shaped anal slit, and V-shaped arrangement of straight setae. b. Epipharynx, showing specific arrangement of striae, spines, setae and pores. Greatly enlarged.

should be examined. The tibial spur of the male terminates more acutely and sometimes in a sharp point whereas that of the female is more obtusely rounded, as shown in Figure 78. The adult beetle is shown in Figures 69 and 77.

LIFE HISTORY AND HABITS

The Japanese beetle has only one generation each year. In Connecticut the adults begin to emerge the last week of June, are at their peak of abundance in July and early August, and decrease until October, when they disappear altogether. Mating occurs soon after emergence. Then the females enter the ground and lay eggs, mostly within two inches of the surface, but at a greater depth if the soil is dry. At first each female lays from one to four eggs, then emerges from the ground and feeds for a day or

two before returning to the soil and depositing another batch of eggs. This continues until all of the eggs have been laid, a total of 40 to 60. Most of the egg-laying is done in July, but some the first part of August or even later in the season. The eggs hatch in about two weeks.

The adult beetles are very active on warm sunny days and are usually quiet in stormy or cloudy weather. They are strong fliers and dart swiftly back and forth through the air from one plant to another. Gregarious in habit, they congregate in large numbers on the flowers, foliage and fruit of certain kinds of food plants. Their adult life is usually from 30 to 45 days.

After hatching, the tiny larvae feed upon the smaller roots of grass and other plants and upon organic matter in the soil. They pass through three

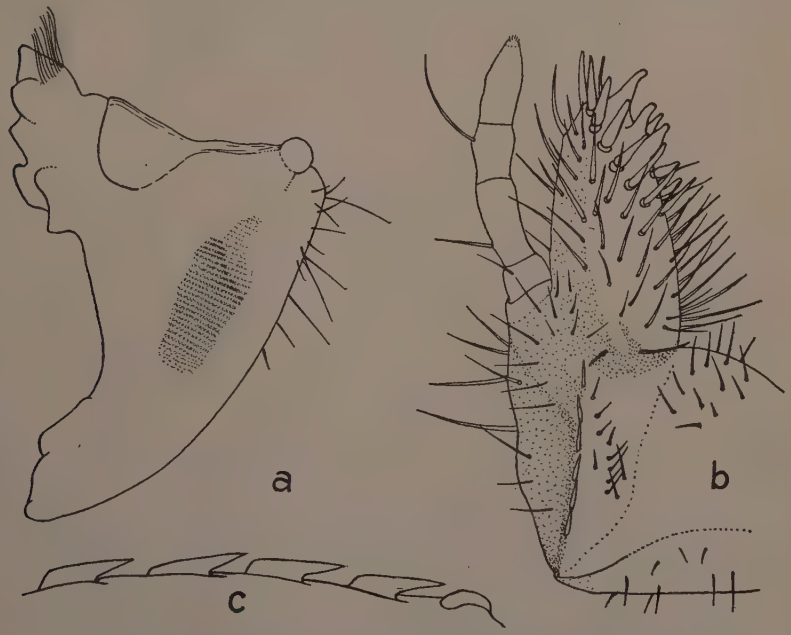

FIGURE 75. a. Right mandible, showing central file-like stridulating area. b. Left maxilla, showing at base a row of six stridulating hooks that are apposed to the file-like area shown in "a". Terminal portion of maxilla is a single lobe, the mala. c. The anterior four stridulating hooks more highly magnified. All greatly enlarged.

distinct larval stages or instars, molting or shedding the skin at the end of each. The first instar larvae feed for about three weeks and reach a length of approximately one-fourth inch. Second instar larvae feed for a similar time and become about half an inch long. During the third instar, they reach a length of from three-fourths to one inch, usually late in September. It is in this stage that most of them pass the winter, although a small proportion may overwinter in the second, or even the first, instar.

When feeding, the larvae are near the surface of the soil, usually in the upper two inches. On the approach of cold weather they descend to a

depth of between two and six inches, where they rest until the following April. Then they return to the upper two inches and resume feeding. They complete their larval growth in June, and spend about 10 days in the inactive prepupal stage, whereupon they transform in cells in the soil to true pupae, a stage lasting from 8 to 20 days, depending upon temperature and moisture. Then the adults emerge.

The entire life cycle usually requires one year, most of the time being spent in the larval stage. This may be summarized as follows: Egg–10 days; larva—11 months (July to June); pupa—14 days (June and July); adult—30-45 days (July to September). As transformations do not occur at the same time with all individuals there is some overlapping of dates. Rarely, individuals may take two years for their life cycle, but there is no evidence that this actually occurs in Connecticut. The seasonal life history is shown in Figure 79.

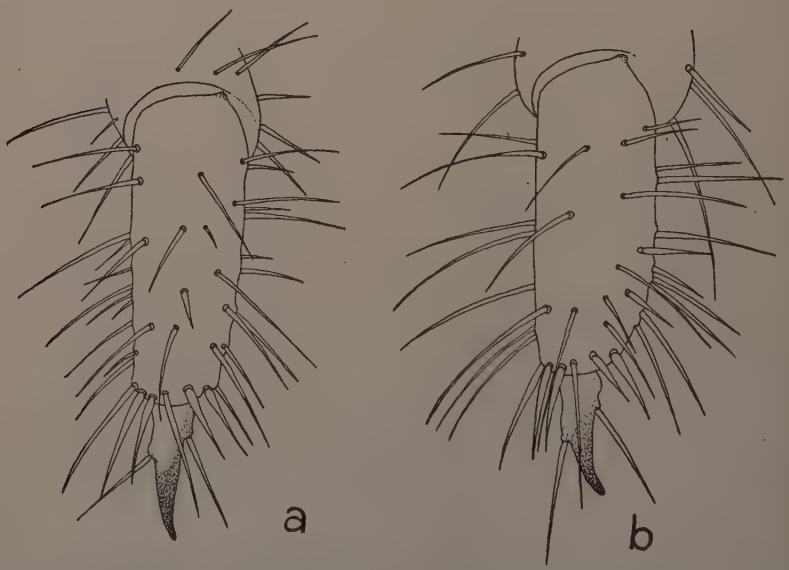

FIGURE 76. a. Terminal segment of the first leg of the larva. b. Same of the third leg. Note that the claws at the tips of the legs are about the same size, but not quite the same shape. Greatly enlarged.

DAMAGE AND FOOD PLANTS

Injury by Adult Beetles

On the whole, the adults are more injurious than the larvae. Damage by the adults occurs only on preferred food plants when the beetles are abundant. In all cases the degree of injury depends upon the number of beetles. Although more than 250 species of food plants have been recorded

in New Jersey, many of them are not of economic importance. The list prepared by Hadley and Hawley (9), however, indicates the more common food plants, including economic species. The list is as follows, those marked with an asterisk (*) being particularly attractive to the beetles.

FIGURE 77. Japanese beetles. About twice enlarged.

PLANTS OFTEN ATTACKED BY THE JAPANESE BEETLE

Small fruits:
- Blackberry, foliage and fruit
- Blueberry and huckleberry, foliage and fruit
- Currant, red varieties
- *Grape, foliage
- *Raspberry, foliage and fruit

Orchard fruits:
- *Apple, foliage and especially fruit of early ripening varieties
- *Cherry, foliage
- Peach; injury severe on fruit of early ripening varieties and occasionally severe on foliage
- Plum, foliage and fruit
- Quince, foliage

Truck and garden crops:
- Asparagus, Beans, Rhubarb } foliage
- *Sweet corn, foliage, silk and ear

Field crops:
- Alfalfa
- Clover, foliage and flowers
- *Field corn, foliage, silk and ear
- *Soybean, foliage

Ornamental shrubs and vines:
- Barberry
- Butterflybush, flowers only
- Crapemyrtle, foliage and flowers
- Lespedeza
- Oriental flowering cherry
- *Rose, foliage, buds and flowers
- *Shrub-althea, flowers
- *Virginia creeper, foliage

Flowering garden plants:
- Canna, foliage and flowers
- *Dahlia, foliage and flowers
- *Hollyhock, foliage and flowers
- *Marshmallow, foliage and flowers
- Rosemallow, foliage and flowers
- Snapdragon, especially flowers of dark-colored varieties
- *Zinnia, flowers and foliage

Shade trees:
- *Elm, *Horsechestnut, *Linden, *Lombardy poplar, Norway maple, Pin oak, Sycamore, White birch, *Willow } foliage

Weeds and other non-economic plants:
- Alder
- *Bracken
- Dock
- *Elder
- *Evening primrose, foliage and flowers
- *Indian mallow or velvetleaf
- *Sassafras, foliage
- *Sensitive fern
- *Smartweed, foliage and flowers
- Tear thumb
- *Wild fox grape, foliage
- *Wild summer grape, foliage

In Bridgeport, Conn., foliage of grapevines was severely riddled and a large Virginia creeper vine was defoliated in 1933. Many dahlia blossoms were ruined, and hollyhock, canna and althea flowers were severely damaged. There was also feeding damage to rose foliage and blossoms, and to the tender terminal leaves of apple and cherry. In Ridgefield in 1932, the beetles seemed to prefer rose, grapevine and heliotrope, the last not being included in the list as a preferred food plant.

The beetles are now rapidly increasing in abundance in Connecticut. If they are not checked, they will certainly damage many crops, trees and ornamental plants that are untouched when a comparatively few beetles are present.

Injury by Grubs or Larvae

Lawns, golf greens and pastures are injured by the grubs or larvae which devour the roots of grass just beneath the surface. This damage usually

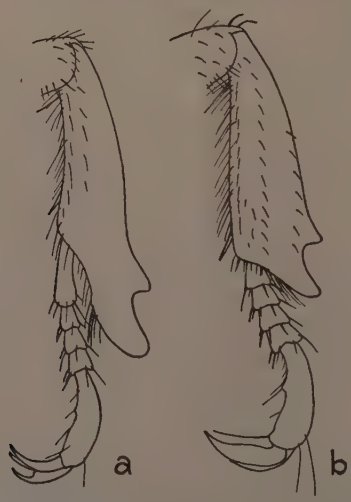

FIGURE 78. First right leg of Japanese beetle. a. Female; b. Male. Greatly enlarged.

results in the destruction of the perennial grasses which are replaced by unsatisfactory annual grasses or weeds. Possibly Japanese beetle grubs are not as dependent on living grass roots for food as are certain other species of Scarabaeid betles, because they feed to some extent on the roots of weeds and flower garden plants and also on the decaying vegetable matter in the soil. Feeding has also been recorded on the roots of bean, corn, strawberry, tomato and other vegetable and field crops. As many as 1,531 grubs have been counted in one square yard of golf green. Under ordinary conditions, 100 grubs per square yard may be sufficient to kill the grass in spots, particularly during dry periods, or if from other causes the turf is not in a healthy condition. When infested to this extent, the turf should be treated.

METHODS OF SPREAD

As the Japanese beetle is a strong flier, infestations may spread from 5 to 10 miles each year through normal flight. It has been said that the beetles usually fly against the wind rather than with it because the wind brings to them the attractive odors of their preferred food plants. Probably, however, they are not very active in flight during stormy, windy or cloudy weather, but there have been severe storms in which beetles have been driven many miles by wind and carried by water.

The beetles often alight on the clothing of persons, enter motor cars, trolley cars and railroad trains, and may be carried hundreds of miles before they escape. They also hide in crates of fruit, vegetables and other produce, and even in machinery, hardware and structural steel. The possibilities of long distance transportation are very great. In the spread of this insect the new infestations have usually occurred along the lines of the movement of motor vehicle traffic and freight shipments.

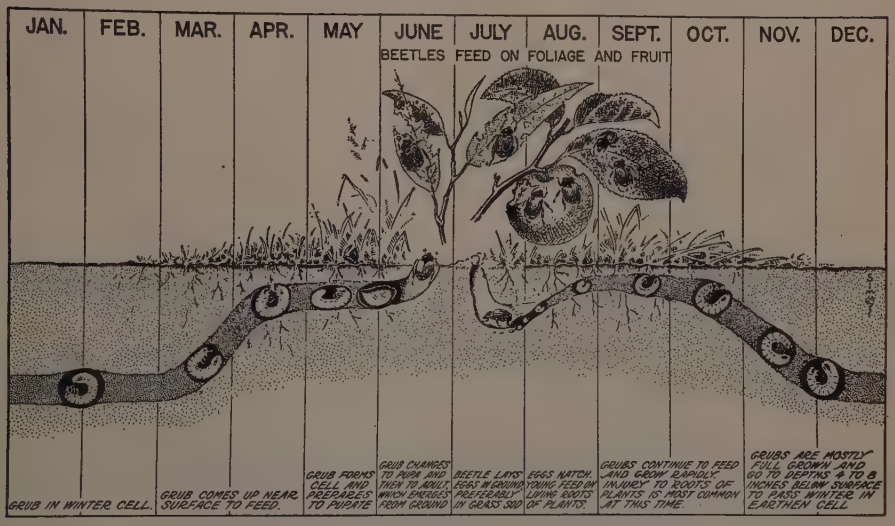
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
BEETLES FEED ON FOLIAGE AND FRUIT
GRUB IN WINTER CELL.
GRUB COMES UP NEAR SURFACE TO FEED.
GRUB FORMS CELL AND PREPARES TO PUPATE
GRUB CHANGES TO PUPA AND THEN TO ADULT WHICH EMERGES FROM GROUND
BEETLE LAYS EGGS IN GRASS SOD
EGGS HATCH YOUNG FEED ON LIVING ROOTS OF PLANTS.
GRUBS CONTINUE TO FEED AND GROW RAPIDLY INJURY TO ROOTS OF PLANTS IS MOST COMMON AT THIS TIME.
GRUBS ARE MOSTLY FULL GROWN AND GO TO DEPTHS 4 TO 8 INCHES BELOW SURFACE TO PASS WINTER IN EARTHEN CELL

FIGURE 79. Diagram showing the seasonal life cycle of the Japanese beetle. (After Bureau of Entomology and Plant Quarantine, U. S. Dept. of Agriculture).

Grubs or larvae may be transported through the movement of plants in pots or with balls of soil about their roots, or in turf, soil, manure and even sand. In 1931 a heavy infestation was started on an estate in Ridgefield by bringing turf from infested lawns in New Jersey, in violation of quarantine regulations. Although the violator was prosecuted and fined, the damage had been done. Quarantine regulations such as inspection, soil treatment, fumigation and screening have been established to prevent possible shipment of the beetles or their grubs to uninfested regions.

NATURAL ENEMIES

Domestic fowls, particularly hens, ducks and turkeys, will devour adult Japanese beetles that happen to be within their reach, and pheasants are

also said to feed upon them. There are certain other birds that readily eat the beetles. Some of the most important are the European starling, robin, purple grackle, meadow lark, cardinal, catbird and English sparrow. Toads also devour many of them. Undoubtedly some are killed by the larger ground beetles and perhaps other predaceous insects, and some are caught in webs and eaten by spiders.

The grubs are also eaten by certain birds and mammals that dig them out of the turf. Perhaps the most important grub-devouring bird is the European starling, flocks of which settle on the infested lawn and extract nearly all of the grubs in certain areas. Skunks are known to dig holes in infested lawns and grasslands and eat vast numbers of grubs. Other mammals that sometimes eat the grubs are the common mole, pine mouse and short-tailed shrew.

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INSECT PARASITES

The search for natural enemies of the Japanese beetle was inaugurated by the U. S. Department of Agriculture early in 1920. Two entomologists were sent to Japan and Chosen (Korea) to study the native parasites of the beetle (1). Since that time the investigations and search have extended into China (2), India and elsewhere in the Orient. The work in Japan has been carried on up to date and will in all probability continue until the field of new parasites is exhausted or satisfactory results have been obtained in this country. Some 30 or more species of parasites have been studied and many of them sent to the United States. Several species have become established to a greater or lesser extent and three of the most promising have been released in Connecticut. One is a two-winged fly of the Order Diptera, and the other two are wasps of the Order Hymenoptera. Several years may be required to demonstrate their value. These are mentioned separately in the following paragraphs.

A Two-Winged Fly

One of the Tachinid flies, *Centeter cinerea* Ald., a native of Japan, is about the size of the common house fly and has a gray head and thorax and black abdomen and legs. This parasite was released in numbers by the U. S. Department of Agriculture in Bridgeport during the adult beetle season of 1928, and in Stamford during 1929. The adult fly lays its eggs on the thorax of the adult Japanese beetle. The eggs hatch within two days and the young enter into the bodies of the beetle at the place where the egg is attached to the host insect, leaving the empty egg-shell in position. The Tachinid larva feeds internally. As a result the beetle dies approximately six days after the egg has been laid.

The adult fly feeds upon honeydew secreted by aphids and also the nectar of flowers. A few recoveries of parasitized beetles were made in Bridgeport during the year following the release; two years later only one was taken. No recoveries were made in Stamford. Apparently the introduction of the parasite at these locations was not successful at the time. During the month of August, 1937, another colony numbering 600 females and more than 600 males, was released in a park on the banks of the Connecticut River in Hartford. It is hoped that this desirable parasite can

become acclimated and synchronize its activity to that of the adult Japanese beetle. The successful establishment of this parasite would make it an important natural control.

The Spring Tiphia Wasp

This insect, *Tiphia vernalis* Roh., is native to Chosen and somewhat resembles a large winged black ant, about three-eighths of an inch in length, body black bearing white hairs, wings clouded at tip. The adults emerge in May and June and dig or burrow into the soil and lay their eggs upon Japanese beetle grubs. On hatching, the parasite larvae attach themselves externally to their host grubs, feed suctorially during their first stages, and in their last stage devour the remains of the grubs. In May, 1936, the U. S. Department of Agriculture released four colonies in Connecticut, each consisting of 100 females. Three colonies were placed in Bridgeport and one in New Haven. Adult specimens were captured in 1937 from one colony in Bridgeport and the colony in New Haven. In May, 1937, five more colonies were released, two in Ridgefield and one each in Branford, New Haven and New London.

FIGURE 80. Apples partially devoured by Japanese beetles. (After Bureau of Entomology and Plant Quarantine, U. S. Dept. of Agriculture.)

The Summer Tiphia Wasp

Tiphia popilliavora Roh., is a native of Japan and in size, appearance and habits closely resembles the preceding species, except that the wings are dark brown and the adults emerge in August and September instead of in May and June. On September 8, 1937, the U. S. Department of Agriculture released five colonies in Connecticut, each containing 100 females. Three were placed in Bridgeport and one each in Branford and East Hartford.

Both *vernalis* and *popilliavora* have become successfully established in New Jersey and Pennsylvania and similar results are expected in Connecticut.

In the original infested area in New Jersey, a certain proportion of the grubs has been killed by organisms in the soil, probably of bacterial, fungous or eel-worm nature. These are now being studied by the U. S. Department of Agriculture.

ARTIFICIAL CONTROL OF THE ADULT BEETLES

The Japanese beetle is capable of being present in tremendous numbers in its adult stage and is such an important pest that any reasonable method employed to reduce its population may be considered a good control measure. The beetle has chewing mouth parts and is known to feed on over 250 different species of plants. It devours leaves and blossoms as well as certain early ripening fruits. Because it is a general feeder on a great variety of plants, successful control is difficult. Protective measures must be extended to include many host plants. The adult beetles are

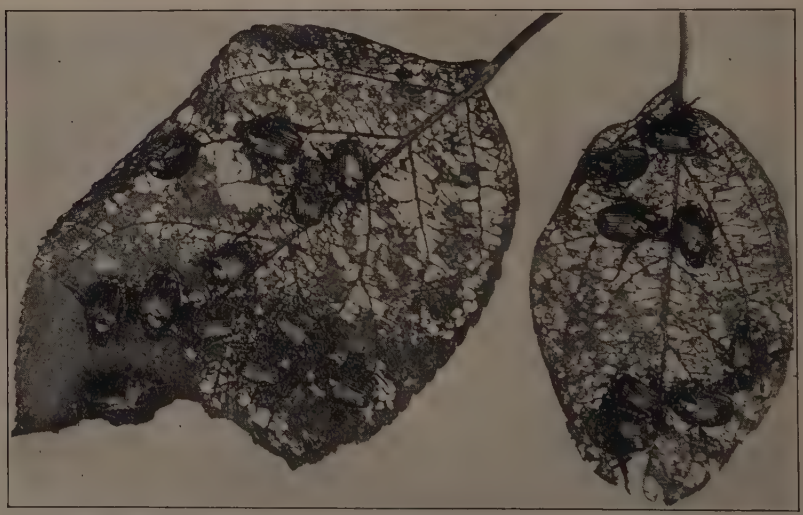

FIGURE 81. Apple leaves partially skeletonized by Japanese beetles. Natural size. (After Bureau of Entomology and Plant Quarantine, U. S. Dept. of Agriculture.)

active, flying with the least provocation on hot summer days when the sun is shining brightly. When the days are cloudy and cool the beetles are quiet and do not fly so much.

Jarring

One of the quickest and easiest methods of control may be accomplished by jarring the beetles from trees and shrubs under which a sheet or canvas has been spread. The catch is then placed in a container holding water covered by a thick layer of kerosene. This should be done in the early morning, before seven o'clock, as the beetles are very sluggish during the cool part of the day. Jarring the individual branches of infested trees and shrubs in this manner is much more efficient than hand-picking. Large

numbers may be disposed of cheaply and effectively by this method. After the beetles have been killed, immediate burial is recommended as they decompose readily and give off very offensive odors.

Trapping

Since the Japanese beetle was found in this country, workers of the U. S. Department of Agriculture have developed a trap for capturing the adults. According to Metzger (10) the most effective bait is a liquid consisting of one part eugenol and ten parts of geraniol, with or without one-half part of phenyl ethyl alcohol, and intended as bait for Japanese beetle traps. The Federal specifications are as follows:

Geraniol—
Specific gravity at 20° C.: .875—.895
Solubility in 70 percent alcohol: 1 part to be soluble in not more than 2 parts of alcohol
Total free alcohols as geraniol and citronellol: 70 percent or over
Ester content: not more than 15 percent
Aldehydes as citronellol: not more than 3.5 percent
Boiling range: not more than 5 percent boiling under 225° C. (at 760 mm.) not more than 18 percent boiling over 245° C.
Odor: absence of any significant indication that materials foreign to geraniol have been added.
Eugenol—U. S. P.

FIGURE 82. Japanese beetles clustered on fruit. (After Bureau of Entomology and Plant Quarantine, U. S. Dept. of Agriculture).

One and one-half ounces of the liquid bait should last five to seven weeks depending on the weather conditions. Solid bait, formerly recommended, consisting of bran, geraniol, eugenol, molasses, water and glycerine, is more expensive and slightly less attractive to the beetles. It also has a tendency to dry out in hot weather and grow moldy in wet weather, which lessens its efficiency. The traps, as illustrated in Figure 83, together with the bait, may be purchased from dealers in agricultural commodities. The outside of the funnel should be light green in color with the inside, the baffle and bait container, white. The paint should have a lustre, as this increases the efficiency of the trap.

The attractive odors are given off by the bait evaporating from a wick extending through the cork of the bottle. The wick should not come in contact with the side of the bait container or trap, as the material will be dispersed too rapidly by capillary action and lost.

A Mason jar of one pint to two quarts capacity is attached to the bottom of the trap as a beetle receptacle. This is a necessary part of the trap, and the pint size is suggested for use in a lightly infested area. A quart jar

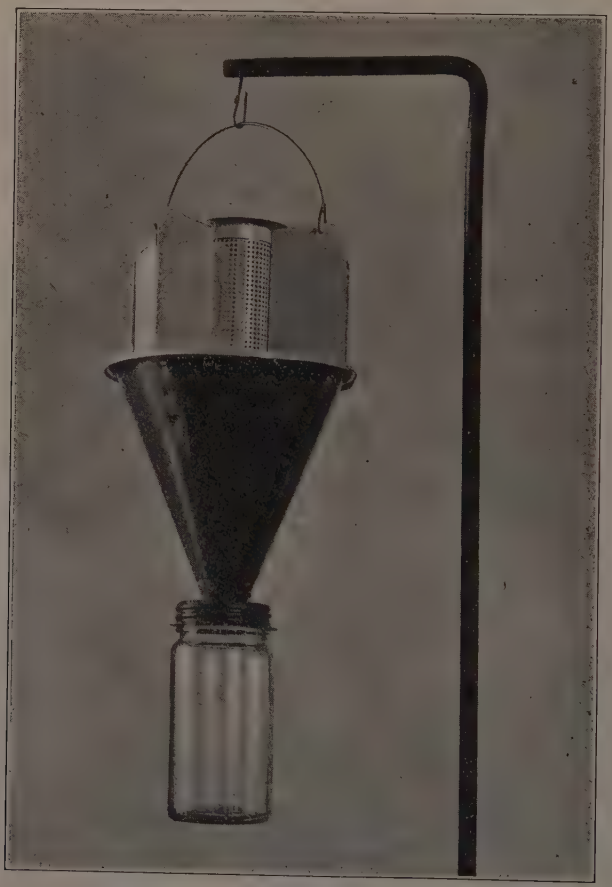

FIGURE 83. A Japanese beetle trap.

will hold approximately 3,300 beetles. It should be emptied regularly into a bucket of water on which there is a thick film of kerosene oil, and the dead beetles should be buried.

Millions of Japanese beetles have been captured in traps throughout the infested area. The traps are exceedingly valuable for light infestations. As we mentioned before, female beetles do not lay their eggs at one time. Therefore many are captured before egg laying has been completed and this

assists in keeping the local infestation at a minimum. The adult beetles in Connecticut begin to emerge from the soil during the last week of June and are present until cold weather. The traps should be placed in position about June 20 and left until October.

When traps are placed in the vicinity of the average home they will probably draw beetles only from the immediate surroundings. Buildings, trees and shrubs have a tendency to deflect or impede air currents which carry the attracting odors. In open fields or large expanses of lawn, and under favorable weather conditions, beetles may be drawn from a distance of 500 yards.

As they migrate in search of favorite food plants or to lay eggs, an influx from adjoining areas may be expected. Thus it is possible for traps to operate efficiently without any noticeable decrease in the beetle population. The beetles will not all be caught in the traps, and if excessive feeding is observed on nearby plants, such traps should be removed 10 or more feet distant. The efficiency of the traps decreases greatly when they are placed more than 25 feet away from plants and shrubbery.

Traps should be placed three to four feet above the ground in the open where the sun shines for the greater part of the day. Special standards may be purchased or made, from which the traps are suspended. One or two, placed in the proper locations in the average property of 50 feet frontage, would assist greatly in reducing the numbers of the Japanese beetle. The use of only a dozen traps in a large city would not be very successful, but concerted coöperative campaigns would be of great value.

Traps alone will not solve the Japanese beetle problem. Their effectiveness varies depending upon the conditions under which they are used. In heavy infestations traps cannot be depended upon to protect favored food plants. In general they will reduce the numbers of beetles and this is a distinct advantage. In fact, many property owners probably will adopt no other control measures and the use of traps should be encouraged. If traps are placed in the garden as early as June 10, they will also catch many rose chafers, *Macrodactylus subspinosus* Fabr.

Spraying

The intensity of the Japanese beetle population has a decided effect upon the manner of spraying as a means of control. Small numbers of beetles are more readily repelled from host plants by protective sprays. However, when an area is heavily infested, protective sprays must be applied before the adult beetles appear. On the other hand, when an area is lightly infested, protective spraying may be delayed until the beetles begin to emerge. The sprays given in this bulletin are those recommended by the U. S. Department of Agriculture (6) and were all tested or developed in the New Jersey area of infestation. The infestation in Connecticut is now of sufficient intensity that experimental work and tests may be made. The federal recommendations have changed from time to time as new methods have been developed, and no doubt they will continue to change until the problem has been fully solved.

Lead arsenate, in combination with a good sticker such as flour or fish oil, may be used at the rate of 6 pounds to 100 gallons of water, to protect

the foliage of late-bearing apple trees, shade trees and shrubs upon which it is customarily sprayed. This insecticide serves primarily as a repellent but also has killing action, giving excellent protection with complete coverage.

A non-poisonous repellent, consisting of one pound of hydrated lime and one-fourth pound of aluminum sulfate to five gallons of water, may be used around the home grounds and elsewhere as desired. Since the adult beetles are repelled from host plants covered with a white spray residue, this material is very desirable. The mixture should be agitated continuously to prevent the lime from settling to the bottom of the container holding it. The spray residue withstands rains very well, but as new growth takes place it is generally necessary to make additional applications during the beetle season.

Flowering Plants.

The rose is one of the primary host plants of the adult beetle and may be damaged severely. Hollyhocks, dahlias, altheas, and zinnias are also important hosts. As a protective spray for flowering plants, derris powder (4 to 5 percent rotenone), one-third pound in 10 gallons of water, will not leave an undesirable residue and gives a fair degree of efficiency. Desirable flowering plants can be protected by covering them with cheese cloth or wire screening. If spray residue is not objectionable, hydrated lime and aluminum sulfate may be used.

Non-flowering Plants.

Lead arsenate in combination with a good sticker or the hydrated lime-aluminum spray may be used to protect large trees, shrubs and vines. Linden, horsechestnut, elm, willow, Lombardy poplar, European white birch, Norway maple and its varieties, sycamore, pin oak, chestnut oak, larch and sassafras trees, are all susceptible to Japanese beetle attack. These trees may also be sprayed with lead arsenate and a good sticker, used at the rate of six pounds to 100 gallons of water, or in small quantities at the rate of two rounded tablespoonfuls to one gallon of water. When the trees and shrubs are large and cannot be covered properly by a hand sprayer, it is best to use a high-pressure machine.

Vegetable Plants.

As the adult beetle feeds upon the foliage of lima and string beans, rhubarb and asparagus, the hydrated lime and aluminum sulfate spray may be applied for protection. Sweet corn is injured by the adult beetles feeding on the green immature silk, which prevents proper pollenization and development of the kernels. This can be prevented by dusting very fine (300-mesh) hydrated lime on the tips of the ears with a hand duster. The material should be applied before the beetles attack the silk, and at least two additional applications should be made at three-day intervals.

Small Fruits and Grapes.

Ripening blackberries, blueberries and raspberries cannot be satisfactorily protected from the adult beetles, as it is next to impossible to remove spray residue without damaging the fruit. The foliage can be protected by spraying with the hydrated lime-aluminum sulfate spray. This

material may also be applied to grapevines to prevent injury by the adult beetles, because the grapevine is one of the most important host plants. Fruit of early ripening varieties may be severely damaged, and the foliage is very susceptible to attack. Grape leaves may also be protected by using 6 pounds of lead arsenate together with a good sticker in 100 gallons of water. A thorough job of spraying is necessary to protect every leaf, and the spray should be directed downward from above to avoid excessive residue on the fruit. New growth must be protected by additional applications through the season.

Protection of Fruit Trees.

Apples and peaches that ripen in July or early August are very susceptible to adult beetle injury, and it is difficult to protect them satisfactorily. Ripe fruit is usually the first to be attacked, and if the beetle infestation is heavy, the ripening fruit will also be damaged.

The foliage and fruit of early apples may be protected by spraying with 5 pounds of aluminum sulfate and 20 pounds of hydrated lime to 100 gallons of water. Diseased or prematurely ripening fruit and that lying on the ground should be removed from the orchard, because the beetles will feed upon it even though heavily coated with the spray residue. Early ripening peaches and plums may be protected by spraying with 3 pounds of derris (5) (containing 4 percent rotenone) and 3 pounds of rosin residue emulsion[1] in 100 gallons of water, provided orchard sanitation is practiced. This spray does not leave an objectionable residue on the fruit at the time of harvest.

Cherries are usually harvested before the adults emerge in great numbers. The foliage of apples, peaches, plums and cherries can be protected by thorough coverage with the hydrated lime-aluminum sulfate spray. It is extremely important that all spraying be done thoroughly to avoid defoliation during a period of heavy infestation, as unsprayed portions of plants will be eaten. During such periods it is often necessary to protect certain crops by using sprays as the fruits and vegetables are ripening, or just before harvesting. The use of the lime-aluminum sulfate spray eliminates some of the objectionable features of spraying at such periods.

Contact Sprays.

Contact sprays are useful in controlling the adult Japanese beetle, but under conditions of heavy infestation they may not afford satisfactory protection. It must be remembered, moreover, that repeated sprays are necessary when the contact insecticide does not leave a poisonous residue or have a repellent action. Pyrethrum contact sprays are very effective in killing the beetle.

PYRETHRUM SPRAYS RECOMMENDED BY THE U. S. DEPARTMENT OF AGRICULTURE. (4)

Formula 1.	Commercial oleoresin of pyrethrum flowers	9.5 ounces
	Oleic acid, U.S.P.	5 pounds
	Sodium hydroxide, C.P.	11.2 ounces
	Water	2.5 gallons

[1] Formula for 50 percent rosin residue: Disperse four pounds of casein in about 45 pounds of water to which 12 ounces of ammonia hydroxide (specific gravity 0.90) has been added; add 50 pounds of rosin residue (residue remaining after the distillation of rosin) slowly with violent agitation and continue until the material becomes emulsified. To prepare the spray add the rosin-residue emulsion to the water in the spray tank and pour a thin paste of the derris into the mixture.

Formula 2.	Extract of pyrethrum flowers	9.5 ounces
	Mixed fatty acids from coconut oil	5 pounds
	Sodium hydroxide, C.P.	15.2 ounces
	Sodium silicate solution (40° to 42° Baumé, composed approximately of 9 percent Na_2O, 29 percent $Si\ O_2$ and 62 percent water	9 fluid ounces
	Water	2.5 gallons

DILUTE EITHER FORMULA 1 OR 2 IN 20 TIMES ITS VOLUME OF WATER

Several contact sprays are made commercially and can be purchased in the open market. It must be remembered that in order to kill the adult Japanese beetle with a contact insecticide, a coarse drenching spray must be used to wet the insect. The most effective contact spraying is done when the beetles are most active in the late morning and early afternoon of a sunny day.

A commercial fish-oil soap or a good grade of household soap used at the rate of one pound of soap to three or four gallons of water may also be effective as a contact spray but should not follow or precede an application of lead arsenate. Care must be taken not to make too many applications on any one plant and not to apply it on very hot, humid days, in order to avoid injury by the soap.

TURF TREATMENT WITH LEAD ARSENATE

As mentioned previously in this bulletin, Japanese beetle larvae feed on the roots of grasses and other plants. A small number of larvae present in the turf does not indicate that the grass will be completely killed by their feeding. However, it does mean that an infestation is present, and it will only be a matter of time before the larvae will be present in sufficient numbers to injure the grass severely.

Under *life history* we have described the life cycle and feeding habits of the grub. In the autumn a drop in soil temperature to 65 or 60° F. sends them to winter quarters about 6 inches below ground level. A rise to about 50° F. in Spring brings them up again and they have been observed feeding just below the surface in April.

Lawns may be examined for infestation by cutting through the turf and rolling it back to expose the under surface. The exposed soil may then be examined by digging, and that in the turf shaken out or loosened with a knife.

Brown or dead patches in turf areas do not necessarily indicate that grubs are injuring the grass. Dry weather, other insects and grass diseases are often responsible for such conditions. Therefore, it is desirable to make an examination before remedial measures are taken. If grubs are found in numbers, lead arsenate may be applied. If there are no grubs and the soil below the turf is very dry, the lawn may merely need watering. Damage to lawns by other insects and grass diseases is described, together with remedies, in Station Circular 113.

The larvae can be controlled by using acid lead arsenate, the kind normally used in spraying operations, at the rate of one pound to 100 square feet (3,7). Other white grubs are commonly mistaken for the Japanese beetle larvae but the control measures are similar. The grubs of the Asiatic garden beetle, *Autoserica castanea* Arrow, and the Asiatic beetle, *Anomala*

orientalis Waterhouse, both introduced species, are approximately the same size as the Japanese beetle larvae while the grub of the *Ochrosidia villosa* Burm., a native species, is slightly larger.

The lead arsenate soil treatment is not recommended for vegetable gardens, flower beds or shrubbery borders. Many vegetables will grow in the treated soil but the lead arsenate absorbed by the plants through their roots may be detrimental to health. Some of the flowers and shrubs react unfavorably to the lead arsenate treatment and it is advisable to leave them untreated. To avoid injury and soil complications the lead arsenate should not be used in amounts greater than those recommended.

Under average conditions it is possible for lead arsenate, applied at the rate of one pound to 100 square feet of area, to be effective for five years. This depends on several factors, such as type of grass, soil structure and constituents, drainage, amount of organic matter, soluble salts present, fertilizer used, and others.

FIGURE 84. View in Hartford, showing the application of lead arsenate to lawn areas to kill the grubs of the Japanese beetle.

It is considered an excellent practice to top-dress turf annually with a good compost high in organic matter, not to exceed one-fourth inch in depth. Lead arsenate should be thoroughly mixed with such top-dressing in alternate years at the rate of two pounds to one cubic yard, before application. This treatment will prevent the accumulation of a non-poisonous layer above the original treated soil. Fertilizers such as well rotted manure, ammonium sulfate, sodium nitrate, potassium chloride, superphosphate, bone meal, activated sludge and tankage, as usually recommended, have been used successfully on treated turf. As lime has a tendency to reduce the effectiveness of the lead arsenate when applied on an alkaline soil, it should be used only when necessary to correct the acidity of the soil.

Methods of Application

In treating turf areas the lead arsenate may be applied in dry form mixed with carriers, or as a spray with water. Any method of application which insures an even distribution over a given area is satisfactory, but the methods employed are usually those adapted to the size of the area to be treated.

When small areas are to be treated, the use of large, expensive equipment may be avoided by applying the chemical in the dry state. This can be done by thoroughly mixing the lead arsenate with about 25 times its volume of moist sand or soil and broadcasting by hand. It can also be applied by using a hand fertilizer distributing machine. When such a machine is employed the lead arsenate mixture should be dry and finely ground to avoid clogging. Satisfactory lead arsenate mixtures are as follows:

(1) One part of lead arsenate, four parts of activated sludge, by weight.
(2) One part of lead arsenate, two parts of activated sludge, four parts of bar sand, by weight.
(3) One part of lead arsenate, ten parts of bar sand, by weight.

It is best to prepare these mixtures just before their application to avoid lumps that may clog the distributors. Upon completing the application, it is advisable to wash off the material remaining on the grass. Do not flood the turf while washing, as this will cause the insecticide to run off or be washed into depressions.

Small areas may also be treated by suspending lead arsenate in water and applying it with a watering can. When this method is used, the insecticide should be diluted at the rate of not less than two gallons of water to one pound of lead arsenate. It is necessary to stir the mixture from time to time during the application. If any lead arsenate remains in the bottom of the watering can, add more water and apply it to the same area. One should be certain that the proper amount of lead arsenate is applied evenly to each area treated.

The use of high pressure power sprayers has proven to be the most economical method of applying the lead arsenate with water to large areas of turf. Power sprayers should be capable of developing 200 pounds or more pressure and have a mechanical agitator in their mixing tanks. The lead arsenate may be placed in the tank at the rate of one pound to two gallons of water. The agitator should be kept in action at all times from the moment before the lead arsenate is placed in the tank until the tank is emptied. When mixed at this rate, every two gallons of mixture applied equals one pound of lead arsenate and it is a simple matter to compute the amounts necessary to treat a given area.

Various nozzles have been employed successfully in applying lead arsenate at this concentration. A Worthley nozzle with a baffle, a quad nozzle, a single nozzle spray rod and an ordinary good quality watering nozzle have all been used satisfactorily. It is advisable to hold the nozzle nearly parallel with the surface of the turf so that the liquid will hit the grass at a narrow angle some distance ahead of the operator. This will

prevent injury to grass which may occur from a close-up pressure delivery, and will also enable the nozzle-man to make a more uniform application. As it is not feasible to drive the power sprayer upon the turf, enough labor should be available to move the hose when necessary without injury to the turf. Before it dries, the lead arsenate[1] should be washed off the grass blades and into the soil where it is needed.

FIGURE 85. View in Bushnell Park, Hartford, showing how water is applied to wash the lead arsenate off the grass and into the soil.

LAWN SEEDING AND TREATMENT WITH INSECTICIDES

It is often necessary to reseed a lawn that has been severely injured by grubs or to build a lawn around a new home in an area of heavy infestation. Such lawns may be treated with lead arsenate in the powder form at the rate mentioned previously for turf treatment. The area should be prepared for seeding and the dry lead arsenate applied evenly over the surface. It should then be mixed thoroughly into the upper two or three inches of soil, leveled and seeded. When this method is used the lead arsenate is incorporated into the actual area where the grubs do their feeding and is immediately ingested, causing death.

Used before seeding, lead arsenate will slightly delay germination. However, if the soil is treated and the seed planted very early in the fall, a good stand of grass can be obtained. Annual bluegrass is retarded in its growth by lead arsenate and is not a satisfactory grass to be grown in treated areas. Redtop, Kentucky bluegrass, Italian and perennial ryegrass, red

[1] Lead arsenate is poisonous. It should be stored under conditions where it is inaccessible to children or animals. Avoid getting the lead arsenate into the mouth, cuts or abrasions. Dogs, cats, poultry or domestic animals should not be allowed to feed on grass which has been treated or under sprayed trees, while any poisonous residue is visible on the grass.
Antidotes: Milk, raw eggs, mustard and water, flour and water. Call a doctor immediately.

fescue, rough-stalked meadowgrass, velvet bent, creeping bent, metropolitan bent, Washington bent, colonial bent, and Rhode Island bent, all grow well in soil treated with lead arsenate.

Many seedings of grass have failed because of the poor germinating qualities of the seed. In case of failure the first time, it is well to replant with seed that has been tested for germination. If an area of heavy infestation is treated and seeded too late in the fall, the retarded germination may result in the loss of the grass stand during the winter.

However, if it is necessary to seed a heavily infested area late in the season, the ground may be treated before seeding with a 70 percent carbon disulfide emulsion[1] diluted at the rate of one quart to 50 gallons of water. Three pints of the material should be applied to each square foot of area. The grubs must be in the upper one or two inches of soil if this treatment is to be effective.

As such a remedy is only a temporary measure, it can be followed by a lead arsenate treatment late in the following spring or early summer, after a good stand of grass has grown. Occasionally late-sown grass may escape injury because the grubs have already gone down to winter quarters. It is well to remember, however, that very late seeding is a questionable procedure because the results are so uncertain. The best results with lead arsenate in an area threatened with turf damage are obtained by treating during July and August when the grubs are small. But the poison may be applied at any time when turf injury is present and the grubs are feeding near the surface. If used late in the fall, it will last over, killing the grubs in the spring. A late spring treatment will do little harm to the current brood, but will be available against the newly-hatched grubs in midsummer.

QUARANTINE AND CERTIFICATION

Since the U. S. Department of Agriculture has extended the Federal Quarantine far beyond the borders of Connecticut, there is no necessity for a State Quarantine and this was revoked, February 10, 1932.

The Federal Quarantine is still in effect and its regulations prohibit the shipment of farm, garden and orchard products as well as cut flowers and portions of plants without roots, between June 15 and October 15, inclusive, of each year; also all plants with or without soil, sand, soil, earth, peat, compost and manure, throughout the year, from the regulated areas to points outside thereof unless inspected and certified. There are certain minor exceptions which are enumerated in the quarantine regulations. Inspection and certification services are maintained by the State[2] in coöperation with the Federal Government.

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[1] **Caution.** Carbon disulfide is a dangerous chemical. The vapor when mixed with air is inflammable. Fires, lighted cigars, cigarettes, or pipes should never be used in the vicinity of carbon disulfide. It is as dangerous as gasoline.

Formula for carbon disulfide emulsion	Part by volume
Rosin fish-oil soap	1
Water	3
Carbon disulfide	10

Dissolve the soap in the water in a closed container and agitate until the mixture is uniform. Then add the carbon disulfide and agitate again until the mixture becomes creamy.

[2] Information and inspection services may be obtained by calling or writing to The Japanese Beetle Control Headquarters, Conn. Agricultural Experiment Station, Box 1106, New Haven, Conn.

Farm, Garden and Orchard Products

All farm, garden and orchard products, to be eligible for certification, must be free from the beetle. It is not always possible to ascertain freedom from infestation by visual inspection, and many products must be fumigated by methods (13) originated and prescribed by the U. S. Department of Agriculture to eliminate the Japanese beetle from shipments requiring certification.

Bananas may be fumigated in carload lots with liquid hydrocyanic acid gas or calcium cyanide. The liquid hydrocyanic acid gas is used at the rate of six ounces to one carload and the calcium cyanide (88 percent) at the rate of three pounds to one car. The temperature of the cars must be 75° F. and prepared according to the regulations under the supervision of an inspector. Because of its danger to human life, this gas should be used only by experienced operators.

It is not feasible or possible to inspect berries visually or mechanically without injuring the fruit. They may be fumigated in specially designed gas-tight chambers with carbon disulfide or ethylene dioxide. The chambers should be equipped with heating units to maintain the temperatures necessary for the treatments. Special outside valves are needed as the fumigants must be introduced into the chambers after all openings are closed and sealed. A special heating unit is used in volatilizing the carbon disulfide. Carbon disulfide, at a chamber temperature of not less than 80° F., is used at the rate of 10 pounds to 1,000 cubic feet for two hours. The ethylene oxide is used at the rate of two pounds to each 1,000 cubic feet and the chamber temperature should be 75° F. or higher. The fumigation period for this insecticide is also two hours. The chambers should be aerated immediately after the termination of the fumigation period.

Nursery and Greenhouse Products

As the Federal Quarantine regulations also prohibit the movement of plants with or without soil to points outside of the regulated area, and govern their movement into establishments classified under the regulations, methods have been devised to treat plants to meet the quarantine requirements. The soil about the roots of many varieties of plants may be removed by shaking or washing, but others have thick, matted root systems which cannot be cleaned in this way. Still others have tuberous or thick, fleshy roots which cannot be properly inspected. Some of them, when in a dormant state, may be treated by immersing their roots in hot water maintained at a constant temperature of 112° F. for 70 minutes. They may also be immersed for a period of 24 hours in a carbon disulfide emulsion (a stock emulsion containing 50 percent carbon disulfide diluted at the rate of 45 cubic centimeters in 10 gallons of water) at a temperature maintained between 65 and 70 degrees Fahrenheit. The varieties of plants which may be treated successfully by these methods are limited and, as official supervision is necessary, it would be advisable to treat only those plants recommended by the Federal Department.

Tremendous numbers of plants are grown in pots in the greenhouse or in nurseries outdoors. Many of those grown in the field are dug with a soil ball, and burlap is tied about the roots. These plants are offered for sale and often require certification for shipment. As it is not possible to inspect

them visually, prescribed treatment is necessary. The pot or soil balls under six inches in diameter may be treated by plunging them in soil containing paradichlorobenzene (14). The amount of this insecticide used and the period of exposure are determined by the size of the soil or pot ball to be treated and the minimum soil temperature during the treatment. The number of varieties of plants successfully treated by this method is limited.

Field grown nursery stock that cannot be treated by the paradichlorobenzene method may be treated in place, while dormant, with a dilute solution of a 50 percent miscible carbon disulfide and water or with lead arsenate. The amount of miscible carbon disulfide and water used varies according to the size of the collars, placed in the soil about the plants, and the soil temperature. Official instructions regulate the conditions under which this type of treatment can be made.

Lead arsenate applied at the rate of 1,500 pounds to an acre may be used to treat blocks of nursery stock in the field. The insecticide must be worked into the upper three inches of soil according to prescribed methods. If it is desired to have such treated stock certified for fall shipment, the initial application must be made prior to July 1. In order to maintain lethal concentrations of the insecticide in the soil, official analyses are made each year as a guide for subsequent re-treatments. This method of soil treatment with modifications may be applied to beds, hot beds, cold frames and individual plants.

Sand, Soil, Earth, Peat, Compost and Manure

As these products are potential carriers of the beetle they must be free of infestation before shipment to points outside of the quarantined area. The quarantine regulations also prohibit the movement of these products from infested areas to establishments classified under the regulations. Methods of treatment have been developed and are prescribed to eliminate all infestation in this group of materials. In the absence of plants, carbon disulfide at the rate of one pound to one cubic yard may be used in a gas-proof container to fumigate them. The temperature of the fumigated material should never fall below 40° F. and the treatment should never be less than 48 hours in length.

When these materials are dry or friable, they may also be treated by heating the mass to a temperature of 130° F. and maintaining it for 30 minutes.

Flake naphthalene, free from tar, when mixed at the rate of five pounds to one cubic yard, may be used to fumigate potting soil that is dry or slightly moist. The soil temperature should not fall below 50° F. After the flake naphthalene has been thoroughly mixed with the soil, it should be left undisturbed for seven days. It is not necessary to use a container, but the mixing should be done on flooring or concrete.

Lead arsenate, when thoroughly mixed at the rate of two pounds to one cubic yard of friable or dry potting soil, may be used to pot certain plants free from soil. Afterward these are plunged in beds or frames that have also been treated. Plants must be potted in this way by August 1, before

the larvae hatch from the eggs. They may be carried over into a second year if an analysis of the soil indicates that the lead arsenate content remains at the original concentration.

Treatment of Temporary Storage Grounds

It is often desirable to treat a plot of ground in order to free it of infestation for temporary storage of certified plants. There are several methods prescribed by the regulations for such areas. When the soil temperature remains at 40° F., or above, carbon disulfide may be injected at the rate of 21 cubic centimeters in holes one to two inches deep, and twelve inches apart. The holes should be filled immediately and the entire area covered with a tarpaulin for 48 hours. Wet soil cannot be treated successfully.

A 50 percent miscible carbon disulfide diluted in water and applied at the rate of 2.5 gallons of solution to each square foot of area will also eliminate a soil infestation. The amount of the insecticide used varies with the soil temperature and is prescribed by the regulations together with the method of application.

Flake napthalene, free from tar, is also prescribed. When the soil is friable and in good tilth and its temperature is 50° F., or above, it may be treated by uniformly distributing this insecticide at the rate of 46 pounds to 1,000 square feet of area and thoroughly working it into the upper three inches of soil. The soil should not be disturbed for one week after the treatment.

SUMMARY

The Japanese beetle, *Popillia japonica* Newman, although not a serious pest in Japan, has become so in the northeastern portion of the United States. It was first discovered in a nursery near Riverton, N. J., in 1916, and appeared in Connecticut at Stamford in 1926. All cities and the larger villages in Connecticut are now infested and considerable damage has been noted, but the insect has not yet become a pest in the country districts.

The Japanese beetle has one generation each year. The adults begin to emerge the last week of June, are at their peak of abundance in July and early August, and then decrease and disappear altogether in October. Eggs are laid in the turf, mostly in July, in batches of one to four, until each female has laid 40 to 60. These eggs hatch in about two weeks. The tiny larvae or grubs feed near the surface upon the roots of grass, and pass through three distinct stages. In the third stage, on the approach of cold weather, they descend two to six inches beneath the soil surface and pass the winter. They ascend to the upper two inches of soil in April, feed for a time, and then become inactive prepupae, in cells in the soil. Later they transform to true pupae. The adults emerge after 8 to 20 days.

Both grubs and adults injure plants. The adults cause greater damage than the grubs because they feed upon the foliage, fruit and flowers of many kinds of trees, shrubs, vines and flowering plants. Some of the preferred food plants are grape, Virginia creeper, rose, raspberry, apple, cherry, sweet corn, dahlia, hollyhock, zinnia, elm, linden, willow, sassafras and smartweed. Altogether more than 250 different food plants have been recorded in New Jersey.

The beetles are strong fliers and very active on warm sunny days, but are usually quiet in stormy or cloudy weather. They congregate in large numbers on ripening apples and peaches. The normal life of the beetle is from 30 to 45 days.

Damage by the grubs is chiefly to lawns, golf greens and pastures, because the grubs devour the grass roots. To some extent they feed on roots of vegetable and garden plants.

Beetles may spread 5 to 10 miles each year through flight, and may be carried on clothing, or in cars and on trains for hundreds of miles. They also hide in shipments of produce and other commodities. Grubs may be carried in soil about the roots of plants, and in turf, loam, manure and sand.

The egg is white, about one-sixteenth of an inch in diameter and somewhat elliptical, but it approaches a globular shape and increases in size before hatching. The mature grub is about an inch in length, whitish, with a light brown head, and resembles a common white grub. The pupa is tan in color and about half an inch in length. The adult is slightly less than half an inch long and one-fourth of an inch broad, with head, thorax, abdomen and legs bright green, and wing-covers copper brown. There are two patches of white hairs at the apex of the abdomen, and five patches along each side, that show outside the wing-covers.

Natural enemies are domesticated fowls, pheasants, and some of the smaller native and introduced birds, among which are the European starling, robin, purple grackle, catbird and English sparrow. Toads devour many beetles, and starlings, skunks, and moles frequently eat the grubs. Soil organisms have destroyed a certain proportion of the grubs in the original infested area in New Jersey. In attempts to control the insect many foreign parasites have been found and imported into the United States. Three of them, one two-winged fly and two digger wasps, have been liberated in the infested area, including Connecticut.

The adult beetles may be controlled by (1) jarring, (2) trapping and (3) spraying. Sheets are spread under infested grapevines, roses and shrubs in the early morning and the plants jarred. Many of the beetles drop upon the sheets and these, together with those caught in the traps, can be destroyed by throwing them into a pail of water with a film of kerosene on the top. To avoid a stench, the dead beetles should be buried. The foliage of trees, shrubs and plants not in flower or bearing ripe fruit can be protected with a spray of lead arsenate at the rate of 6 pounds in 100 gallons of water. On ripening fruit and on plants where poisons are objectionable, a non-poisonous repellent spray of one pound hydrated lime and one-fourth pound aluminum sulfate in five gallons of water will give protection.

Grub damage to lawns may be controlled by applying to the surface acid lead arsenate at the rate of one pound to 100 square feet. One pound will prevent lawn damage for five years. In case of a heavy infestation, when a quick kill is desired for reseeding, or if there are real objections to lead arsenate, the lawn may be treated with a 70 percent carbon disulfide emulsion diluted at the rate of one quart in 50 gallons water. This will have no residual effect.

The State Quarantine was revoked February 10, 1932, but the Federal

Quarantine is still in force. Between June 15 and October 15 all shipments of farm, garden and orchard products, as well as cut flowers and portions of plants without roots must be inspected and certified. Also all plants with or without soil on the roots, and any shipments of sand, soil, earth, peat, compost and manure, from the quarantined area to points outside must be inspected and certified at all times. In generally infested regions, treatment of the soil or other material by fumigation, carbon disulfide or naphthalene may be necessary as a requirement for certification.

LITERATURE

Many notes and articles about the Japanese beetle in Connecticut will be found in the Reports of the State Entomologist of Connecticut, published as bulletins of the Connecticut Agricultural Experiment Station, as follows: Bul. 285, p. 244, 1926; Bul. 294, p. 281, 1927; Bul. 305, p. 737, 1928; Bul. 315, p. 588, 1929; Bul. 327, p. 548, 1930; Bul. 338, p. 558, 1931; Bul. 349, p. 411, 1932; Bul. 360, p. 440, 1933; Bul. 368, p. 206, 1934; Bul. 383, p. 304, 1935; Bul. 396, p. 346, 1936; Bul. 408, p. 185, 1937. The publications on the Japanese beetle are so numerous that only a few of the more important papers are given in the following list:

1. Clausen, C. P., Jaynes, H. A. and Gardner, T. R. Further Investigations of the Parasites of *Popillia japonica* in the Far East. Technical Bulletin No. 366, U. S. Dept. Agriculture, 1933.
2. Clausen, C. P., King, J. L. and Teranichi, Chia. The Parasites of *Popillia japonica* in Japan and Chosen (Korea) and Their Introduction into the United States. Dept. Bul. No. 1429, U. S. Dept. Agriculture, 1927.
3. Fleming, W. E. Preventing Injury from Japanese and Asiatic Beetle Larvae to Turf in Parks and Other Large Areas. Circ. No. 403, U. S. Dept. Agriculture, 1936.
4. Fleming, W. E. Contact Sprays for the Japanese Beetle. Circ. No. 280, U. S. Dept. Agriculture, 1933.
5. Fleming, W. E. and Metzger, F.W. Control of the Japanese Beetle on Fruit and Shade Trees. Circ. No. 237, U. S. Dept. Agriculture. Revised 1936.
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7. Friend, R. B. The Asiatic Beetle in Connecticut. Bul. No. 304, Conn. Agr. Exp. Station, 1929.
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12. Safro, V. I. Questions and Answers on the Japanese Beetle. Circ. No. 152, New Jersey State Dept. Agriculture, 1929.
13. Service and Regulatory Announcements, Jan.-Mar. 1934: S.R.A.—B.P.Q. No. 118, Bureau of Plant Quarantine, U. S. Dept. Agriculture, issued May, 1934.
14. Service and Regulatory Announcements, Oct.-Dec., 1937: S.R.A.—B.E.P.Q. No. 133, Bureau of Entomology and Plant Quarantine, U. S. Dept. Agriculture, issued 1938.
15. Smith, L. B. and Hadley, C. H. The Japanese Beetle. Dept. Circ. 363, U. S. Dept. Agriculture, 1926.